LESC RESPONSE to
DOE Team Interim Recommendation #1 – ATS Item 2944.5.3

DOE Recommendation
With exception noted below, dress for Hazard Category 2 for 480V circuit breaker and switch operation (Exception – 480V panels where incident energy is sufficiently high that higher hazard category clothing is required or where operation is too dangerous to be performed manually)
Laboratory Response:
As of the receipt of this recommendation, the Laboratory had issued interim PPE requirements that met or exceeded the team's recommendation. They will remain in place until the following actions are completed].

Resulting BNL Action Pan
• Review the NFPA 70E standards and determine the adequacy of the recommended personal protective equipment to protect workers to a level consistent with Laboratory safety goals, for all operations, including switching operations.
• If indicated, upgrade, the Laboratory Electrical Safety Standards to better address arc-flash personal protective equipment.
• Publish the upgraded standard in SBMS and/or local procedures, as appropriate

Background
As an immediate interim action in response to the Type B team recommendations BNL revised its PPE requirements to be more protective, this was accomplished by a memo signed by J.Tarpinian, ALD ESH&Q. Concurrently, the CA Department revised their internal procedures upgrading PPE requirements but with differing requirements than the J. Tarpinian memo. These two sets of PPE requirements created confusion for those workers working in both areas. A working group under A. McNerney, ALD F&O, was established to consolidate the two sets of procedures. The Laboratory Electrical Safety Officer (LESO) was asked to update the Personal Protective Equipment (PPE) tables for working energized requiring more stringent PPE consistent with the recommendations made by the working group for switching until a more detailed review could be undertaken by the Laboratory Electrical Safety Committee (LESC). The resulting changes were published as Appendix VIII of Electrical Safety Standard 1.5.0 in SBMS.

Actions Taken by LESC
To provide a better basis for understanding PPE requirements, the LESC solicited input from other knowledgeable sources including:

- DOE Electrical Safety community, through the DOE Electrical Safety list-serv
- DOE Facility Managers, through a questionnaire (Appendix 1).

In addition, data on electrical equipment maintenance obtained from the Plant Engineering Maintenance Management Group (Appendix 2) and was assessed against the recommendations of NFPA 70B, "Recommended Practice for Electrical Equipment Maintenance". Specific requirements of NFPA 70E Articles 210 and 225 specifically dictate that breakers and be inspected and tested in accordance with manufacturers instructions.

Discussion
Before one can discuss PPE one has to understand the risks a worker is potentially exposed to even while wearing PPE. NFPA 70E defines the arc-rating of PPE as:

Arc Rating. *The maximum incident energy resistance demonstrated by a material (or a layered system of materials) prior to breakopen or at the onset of a second-degree skin burn. Arc rating is normally expressed in cal/cm2.*

In essence this is saying that a worker wearing say 25 cal/cm^2 clothing, which is the protection required for Risk/Hazard Category 3 with spans from 8 – 25 cal/cm^2 could receive up to the onset of a second degree skin burn and that the clothing PPE should resist breakopen. However, a 25

cal/cm^2 exposure represents the top of the limit and statistically during an arc-flash (a low probability event) the exposure should be less. The attached table illustrates that the probability of a second degree bun goes down as the exposure goes down from the PPE arc-flash rating, referred to as ATPV or arc-temperature performance value.

ARC15—Arc Rating[1](ATPV) 15 cal/cm²

Probability[2] of 2nd degree Burn or FR Fabric Breakopen	ARC15 Suit[2] No Underlayers	ARC15 Suit over 4.5 oz/yd² FR Daily Workwear[2,3]	ARC15 Suit over 4.5 oz/yd² FR Daily Workwear & Cotton Longjohns[2,3,4]
50%	$ATPV_{50}$ **15**	$ATPV_{50}$ 24	E_{BO50} 46
40%	$ATPV_{40}$ **14**	$ATPV_{40}$ 23	E_{BO40} 46
30%	$ATPV_{30}$ **14**	$ATPV_{30}$ 22	E_{BO30} 45
20%	$ATPV_{20}$ **14**	$ATPV_{20}$ 21	E_{BO20} 44
10%	$ATPV_{10}$ **14**	$ATPV_{10}$ 20	E_{BO10} 43
5%	$ATPV_{5}$ **14**	$ATPV_{5}$ 19	E_{BO5} 42
1%	$ATPV_{1}$ **13**	$ATPV_{1}$ 17	E_{BO1} 40
Min. Hood Requirement	Oberon ARC15	Oberon ARC25	Oberon ARC40

(1) The Oberon ARC15 Arc Rating is determined without consideration of undergarments. Testing and manufacture is in accordance with ASTM F1506-02a and F1959-99. The Arc Rating(ATPV) is defined as "the incident energy on a fabric or material that results in a 50% probability that sufficient heat transfer through the tested specimen is predicted to cause the onset of a second-degree skin burn injury based on the Stoll curve" according to the proposed ASTM F1959 revision.

(2) The ASTM F1959 Proposed Logistic Regression Data Analysis is used to determine the incident energy in cal/cm^2 level for a 50% probability of a 2nd degree burn injury ($ATPV_{50}$) or for a 50% probability of Breakopen of all FR layers (E_{BT50}). The incident energy is also determined for lower probabilities of 2nd degree burn or breakopen of all FR fabrics.

(3) Arc Testing results for the Oberon ARC15 Suit when tested over FR work clothing with min. weight of 4.5 oz/yd^2 Nomex®IIIA. The FR work clothing can be a long sleeve shirt and pants or a long sleeve coverall.

(4) Arc Testing results for the Oberon ARC15 Suit when tested over FR work clothing with minimum weight of 4.5 oz/yd^2 Nomex®IIIA in addition to a cotton under-layer with a minimum weight of 5.5 oz/yd$_2$. The FR work clothing can be a long sleeve shirt and pants or a long sleeve coverall. The cotton under-layer can be cotton longjohns or a cotton long sleeve shirt and pants.

Warning – A hood with a higher Arc Rating will be required to protect the head and face as noted above in the bottom row of the table.

It is the opinion of the LESC that the risks imposed by exposes postulated during the formulation of the standard are reasonable and should be considered as “standard industrial risk”. They are no different then the risks we face from other events some of which have substantially higher probabilities such as driving the vehicle to the work site. We feel the risk is similar to that of a worker protected from a fall with a harness who could fall and injure their back, but the harness would prevent the more catastrophic risk such including death.

While accepting this level of risk, the primary concern the LESC has is that BNL was relying on the PPE tables contained in NFPA 70E 130.7(C)(9)(a) without full regard for the bounding conditions set forth in the tables which limit its use to only when certain conditions of short-circuit and protective device response time have been verified. This subjects workers to potentially greater risk then the code anticipated. BNL has not ignored this risk, and in many cases where work planning was used to identify the hazards for select cases where it was clear the hazards may be significant such as when working close to transformer secondary terminals where the short-circuit currents are significant. However, this was not carried out in the more routine

activities where hazards could exist. The ultimate solution for these issues is as required by NFPA 70E Article 130.3 is that an Arc-Flash Analysis be performed to determine the actual hazards level for specific equipment. While this effort has started, much work is needed and it is reasonable that BNL compensate in the interim by taking a more conservative approach to PPE selection where specific arc-flash analysis has not been performed, thus reducing the risk.

During the review we have uncovered other issues which we feel contribute to the risk, though not as primary as the arc-flash calculations, we feel these should be considered.

Additional requirements for ensuring safe working conditions are:

- Safety systems, such as protective devices are maintained in a manner to reasonably ensure proper operation
- That only qualified personnel, who have been properly trained to recognize and mitigate the hazards, are exposed to equipment with the potential for shock or arc-flash hazards, and then only when necessary. Otherwise, it is always required to make circuits electrically safe, unless specifically documented and justified in an Energized Work Permit.

Reviewing the first element, maintenance, the committee had concerns. A report completed by Plant Engineering in 2004, estimated that only 70% of the electrical maintenance was being performed. Since that time overall budget limitations and overtime restrictions leave us no reason to believe any improvement in the situation has occurred.

Having protective devices such as circuit breakers not operate or operate slower than designed could have catastrophic effects in terms of increased arc-flash incident energy. As an example, BNL has a history of finding Low-Voltage Power Circuit Breakers (LVPCB's) that would not trip or operated outside their tripping-time specifications. Fortunately, the breaker protecting the panel at CA-D, where the recent arc-flash occurred was not one of the ones experiencing trouble, had it been the fault at the panel could have released 10-15 times the incident energy of the approximately 11 cal/cm^2 calculated.

Thus, one can see the importance of proper maintenance to ensure safety. Conversely, if maintenance is suspect, one should proceed more cautiously in determining appropriate PPE. The issue of LVCB's not tripping is being addressed in part, by the installation of new solid-state trip units; however, this effort still has a long way to go and it is not clear that all LVCB's are being tested on the four year planned cycle, or that that cycle is adequate.

The second element is having qualified workers. NFPA 70E defines this as:

Qualified Person. *One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved.*

As evidenced by this incident and the survey performed afterwards as part of lessons learned it is not clear how effective BNL's electrical safety training program has been to convey the potential hazards of arc-flash to employees. Thus reason to once again compensate in other areas such as PPE selection.

LESC Recommendations

1. Considering the issues described above, the LESC recommends that revisions to the PPE table (ES&H Standard 1.5.0 Appendix VIII) which would tend to be conservative, should remain in effect. In concept, they are similar to the two-category simplified system described in Appendix H of NFPA 70E for electrical worker in facilities with large diverse electrical systems. It further ensures that personnel who could be exposed to significant arc-flash hazards are provided with proper FR clothing. Once arc-flash calculations are performed, and subsequently posted on equipment, the calculation will govern the PPE

selection. This may relax the PPE requirements for some workers; however, those personnel who work on an array of equipment with differing Risk/Hazard Categories should be dressed in FR clothing as a minimum.

2. Perform an evaluation of the maintenance and inspection of electrical equipment, particularly on that equipment whose failure or mis-operation has the greatest potential to cause injury. The evaluation should ensure all protective devices dealing with significant energies such as those related to switchgear, MCC's, and large distribution panels are included in the system and tested and inspected regularly consistent with manufacturers recommendations per NFPA 70E Article 210 and 225.

3. Within the next six months, perform an assessment of the effectiveness of training to convey the potential hazards of arc-flash related incidents to workers.

Submitted By: Original signed by John F. DiNicola
Chair Laboratory Electrical Safety Committee, on behalf of the full committee

Concurrence: Original signed by Michael Bebon, Deputy Director for Operations

APPENDIX 1

DOE FACILITIES MANAGERS QUESTIONNAIRE

1. Have you performed arc-flash calculations for any of your electrical equipment? If so, what is the approximate percentage completed for your site?

Site 1: No

Site 2: Yes we have. There are two parallel efforts, 1) Ongoing for all facilities which started with our highest priority facilities, and 2) All electrical switching and outage procedures are accompanied by task specific arc-flash and boundary distance calculations.

Site 3: No, we are budgeting to do entire site in early FY2007

Site 4: Yes, we have, and we are doing them for approximately 60% of our site

Site 5: All power distribution in the 13.8kV and 2.4kV class have been done up to the first disconnecting device entering a facility. Approximately 10% of the facilities have had or are in the planning stages of having their inside distribution (480V and below) calculations performed.

Site 6: We have done arc flash calculations & Hazard Identification Labels for approximately 30% of our equipment. We have calculated labels at all unit subs and main switchboards. However, where we do not yet have labels installed, we have elected to apply a "worse case" scenario, requiring PPE for the highest incident energy that has been calculated for "like equipment". Note: our policy prohibits "Mode 3" work on any exposed, energized electrical circuits > 50VDC (unless approved in writing by the Laboratory Director). This lessens the impact of not having all equipment labeled.

Site 7: Yes.100% to the panel level.

Site 8: We have done very few arc flash calculations, may be about 5% for the site. Facilities have a good set of single line drawing for the site medium voltage distribution.

2. How do you use these calculations, if at all, to determine PPE required for working on or near? Please consider 208V and 480V, three phase breakers and switches in your response. If you have not performed arc-flash calculations, how do you determine what PPE is required?

Site 1: Using tables of NFPA 70E

Site 2: Since we do perform these calculations, for switching at all voltage levels (208, 480, 4160, & 12470VAC) we use the program recommendations or the arc-flash tables in NFPA 70E.

Site 3: We use the table for PPE requirements in NFPA 70E

Site 4: The incident energy (cal/cm2) at the electrical equipment work location dictates the level of PPE

Site 5: So far with very few exceptions, the calculated arc flash energies require less PPE than the 70E default tables that we are currently using. Where calculations have been done,

calculations are reviewed with permitted work otherwise the PPE requirements are determined via 70E. Under normal conditions, e.g. no problems with switches or breakers and covers are on or doors closed; operation of a three-phase 208V and 480V switch and breaker requires the use of safety glasses, leather gloves, and closed toe shoes. A long sleeved shirt and pants of untreated natural fiber shall also be worn

Site 6: We use a software program "SKM PowerTools" to generate labels with all the relevant boundary distances and arc flash cal/cm2 numbers. We then use those figures to determine the required PPE. Where we have complete systems labeled (such as our experimental halls), we have found that the arc flash hazard reduces the farther you move downstream of the switchboards. Accordingly, In situations where no calculated label exists, we have given our personnel instructions to search out the upstream devices (at the same voltage level) and select PPE based on the labels as shown on that equipment. At some point in the system, there is a calculated label.

Site 7: All switchgear and panels are labeled with required PPE's, Hazard Category, Flash Protection Boundary, and Minimum Arc Rating.

Site 8: Our work is limited to diagnostic energized work and we follow table 130.7

3. How do you use these calculations for operation of switches and circuit breakers with the doors closed? Please consider 208V and 480V, three phase breakers and switches in your response. If you have not performed arc-flash calculations, how do you determine what PPE is required?

Site 1:NO, do not allow

Site 2: Since we do the calculations and wear the appropriate level of PPE in "All" circuit breaker or disconnect switch switching operations, and we use the prescribed methods in NFPA 70E (standing to the side, using qualified craftspeople, and maintaining all appropriate boundaries) so depending on the physical configuration of the circuit breaker or switch, we typically have doors closed!

Site 3: We do not know of any requirement for any PPE to do this and require no special actions.

Site 4: We don't use calcs for the operation of breakers, switches, etc with the door closed and perform this under NFPA 70E Table 130.7(c)(9)(a) as class 0 work. In a few incidents we have evaluated the work and have exceeded NFPA 70E requirements for operation of electrical equipment with the door closed.

Site 5: A: Under normal conditions, the operation of a three phase 208V and 480V switch and breaker requires safety glasses, leather gloves, and closed toe shoes. A long sleeved shirt and pants of untreated natural fiber shall also be worn.

Site 6: When the doors are closed, we use the requirements listed in NFPA 70E, table 130.7(C)(9)(a) and 130.7(C)(10). We believe this is defined as long sleeved cotton shirt, jeans, and safety glasses. That is what we teach in our NFPA 70E class.

Site 7: The arc-flash calculations were performed for the situation where the conductors are exposed. We have not instituted specific PPE requirements for operation of circuit breakers or switches with covers/doors in place.

Site 8: We are following table 130.7 if the calculations are not done.

4. Does your site have interim procedures for determining PPE that differ from the requirements of NFPA 70E (e.g. more stringent requirements)?

Site 1: No

Site 2: We have outfitted all of our craftspeople that may have any need to perform any type of Electrical work activity (Electricians and Mechanical HVAC personnel) with Category two PPE, and with additional layers to get us up to a maximum of 100 cal/cm^2 using the EasyPower computer program application.

Site 3:No

Site 4:We use our arc flash calculator which is more conservative that NFPA 70E at times, and thus takes use to more stringent requirements for PPE

Site 5: There is no site interim procedure addressing that issue. We use the resources and expertise of our ESC (Electrical Safety Committee) members to consider more stringent PPE requirements as circumstances may require

Site 6: No. Back in 2004, we made some initial calculations so that we could direct our internal groups and subcontractors on what level of PPE to purchase for their employees. The results of the calculations revealed that 11 cal/cm2 gear was appropriate for the overwhelming majority of our typical uses. We purchased a few suits that were rated higher in case we had numbers that exceeded those figures. As we get the calculated labels installed, we are directing our subcontractors to observe those numbers.

Site 7: No

Site 8: There are no interim procedures as far as I know.

5. If you have not completed arc-flash calculations, are they part of your work planning processes? If so, please describe.

Site 1: No

Site 2: As noted in question # 1 & #2 above, the answer is yes. We do perform arc flash calculations for switch or circuit breaker switching activities.

Site 3: Yes, work planning requires the proper use of PPE for activity but would use the NFPA 70E chart to determine requirements. As noted, this will change once we get arc-flash calculation completed.

Site 4: Electrical work is evaluated first
- Based on the evaluation we use two methods during our planning process
- We use our Standing Diagnostic Testing & Trouble shooting procedure or De-energization procedure
- Energized Work Permit with complete arc flash calcs and with appropriate level of PPE"

Site 5: The need to perform energized work occurs infrequently, but where it is needed the permit process requires identification of the corresponding energy levels

Site 6: Arc-flash calculations and hazard identification labels for all permanently-connected equipment fed from 208VAC and above are part of our planned electrical safety program.

The analysis work is being done by a combination of in-house staff and outside consulting engineers.

Site 7: If it involves higher ampacity work, work planning might do the arc flash calculations.

APPENDIX 2
PLANT ENGINEERING PREVENTIVE MAINTENANCE

A list of preventive maintenance and MCC and substation related equipment was provided for review and discussion. While there was evidence that some equipment had been inspected and tested per the desired frequency there was also evidence that some had not been. In addition, after discussion it was determined that some equipment may not even be in the system. A review of the data for actual verification is possible but is made difficult in that a new maintenance system was implemented less that two years ago and pertinent information such as the last inspection test date was not past on from old system to new system allowing for direct verification. However, the data can be retrieved and combined to allow review. It was also discussed that this issue was also present the previous time the maintenance system was replaced. This complicates the verification process and creates a credible issue of things being missed.